Working Paper 99-27
Statistics and Econometrics Series 07
March 1999

Departamento de Estadística y Econometría
Departamento de Economía
Universidad Carlos III de Madrid
Calle Madrid, 126
28903 Getafe (Spain)
Fax (3491) 624-98-75

LABOR CONTRACTS AND FLEXIBILITY: EVIDENCE FROM A LABOR MARKET REFORM IN SPAIN

Víctor Aguirregabiria and César Alonso-Borrego *

Abstract

This paper evaluates the effects on employment, job turnover and productivity of a labor market reform in Spain that eliminated dismissal costs for fixed-term contracts. Our empirical results are based on a panel of 2356 Spanish manufacturing firms for the period 1982-1993. We postulate and estimate a dynamic labor demand model with indefinite and fixed-term labor contracts. Our estimations use data on severance payments to identify when negative changes in employment have been associated with costly dismissals. Experiments using the estimated model show important positive effects of the reform on employment (between 2.5% and 4.5%) and job turnover (between five and seven percentage points). However, its effects on productivity and the value of a firm are negligible. This contrasts with the sizeable increases in output and value under a hypothetical reduction in firing costs for all type of contracts. Compared with this alternative reform, the introduction of temporary contracts leads to excess turnover and employment of workers with low firm-specific experience.

Keywords: Labor demand, Firing costs, Fixed-term contracts, Estimation of dynamic structural models.

* Aguirregabiria, University of Chicago. E-mail: vaguirre@midway.uchicago.edu; Alonso-Borrego, Departamento de Estadística y Econometría y Departamento de Economía, Universidad Carlos III de Madrid. E-mail: alonso1@eco.uc3m.es

We want to thank the comments received from Jeff Campbell, Andrés Erosa, James Heckman, Andreas Hornstein, and Ariel Pakes, as well as from seminar participants at the University of Chicago, University of Minnesota, Queen's University, University of Waterloo, University of Western Ontario, and Yale University. We also acknowledge Ricardo Mestre and the staff of the Central de Balances del Banco de España for providing the raw data.

1 Introduction

Regulation of workers' dismissal is one of the labor market institutions most commonly invoked to explain the large and persistent differences between European and North American unemployment rates. From a theoretical point of view, the effect of firing costs on employment is ambiguous. Firing costs reduce hiring during expansions, but these costs also reduce dismissals during downturns. The sign and the importance of the net effect depend on, among other factors, the persistence of aggregate and idiosyncratic shocks, the size of hiring and firing costs, and the rate of workers' voluntary quits. Therefore, it is an empirical question to evaluate how a reduction in firing costs affects employment in a particular economy.

The empirical evidence in the literature is mixed. Using panel data of countries, Lazear (1990) obtains that regulation of workers' dismissal explain an important part of the variability of unemployment rates over time and over countries. Bentolila and Bertola (1990) calibrate a labor demand model using data of several European countries, and obtain negligible effects of firing costs on employment. Hopenhayn and Rogerson (1993) extend this model to a general equilibrium framework with entry and exit of firms. They calibrate this model using US data and obtain that an introduction of firing cost would reduce employment importantly. In this context, the labor market reforms that several European countries have implemented during the last fifteen years provide unique information to identify the effect of firing costs on firms' labor demand decisions.

Labor Market Reforms in Europe

Although the regulation of work contracts differs widely among European countries (see European Commission, 1996, 1997), most labor market reforms carried out in these countries during the eighties and nineties were aimed to reduce costs associated with the dismissal of workers.[1] However, most of these reforms did not reduced firing costs for

[1]During this period, France, Germany, Greece, Italy, Netherlands, Portugal and Spain passed new laws on temporary employment and dismissal costs.

all type of workers or labor contracts. A common feature was the elimination of many previous restrictions to hire and fire workers with fixed-term contracts, i.e., the so-called *temporary* contracts. Before the reforms, temporary contracts were mostly ruled by the principle of causality (i.e., jobs that are occasional or seasonal, or to cover absent posts).

Under the new legislation temporary contracts can be used for non temporary activities. The main differences between temporary or fixed-term contracts and permanent or indefinite-duration contracts are the amount of severance payments, and the degree of dismissal protection on each of them. The reforms allowed a firm to dismiss fixed-term contract workers with low or no severance payments, and without advanced notification to the unions and the Ministry of Labor. However, the regulations and costs associated with the dismissal of workers with permanent contracts barely changed after the reform.

Not surprisingly, the proportion of temporary jobs increased sharply after these reforms. Before the 1984 reform, temporary workers in Spain comprised only 10% of total employment and 2% of manufacturing employment. In 1992, these figures were 33% and 11%, respectively. Spain has become by far the European country with the highest percentage of temporary employment, where temporary contracts represent over 90% of hires. This important increase in temporary employment points out that firms have found these contracts attractive to reduce firing costs. Nevertheless, this behavior is consistent with either positive or negative employment effects of the reform. Evaluating the effects of the reform on employment and output requires one to analyze how individual firms' hiring and firing decisions have changed after the reform. This is the main objective of this paper.

Identification and Econometric Issues

If the extensive use of temporary contracts by firms after the reform were completely exogenous, a simple way to evaluate its effects could be based on a reduced-form regression of the variable of interest on the proportion of temporary employment. However, the existence of firing costs for permanent workers has made the process of introducing temporary contracts very slow and clearly endogenous. Most firms have not fired permanent workers to hire temporary ones. Instead, they have waited for the arrival of positive shocks, and for the retirement of permanent workers, to substitute temporary for permanent contracts. Therefore, part of the estimated effect of temporary employment on output or total employment in this simple reduced-form approach would be endogenous. Furthermore, as we explain in Section 4, it is difficult to find instruments for temporary employment which are uncorrelated with firms' productivity shocks.

The limitations of the former approach motivate our consideration of a more structural method to evaluate the effects of the reform. We postulate and estimate a dynamic model of labor demand with permanent and temporary contracts. The model is similar to the ones in Bentolila and Saint-Paul (1992) and Cabrales and Hopenhayn (1997). Our estimation method comprises two stages. In a first stage we exploit the Markov structure of the model to estimate the production function and to obtain fitted values for the productivity shock. In the second stage we use the estimated values of productivity shocks as observable, and estimate the rest of structural parameters from the dynamic decision model. The method provides consistent estimates of the structural parameters, and avoids the problem of autocorrelated unobservables in nonlinear models. Our estimation procedure of the dynamic decision model is a nested fixed point - maximum likelihood method in the spirit of Rust (1987, 1994).

Given the motivation of the paper, the estimation of hiring and firing costs is particularly important. The identification of these parameters is based on two predictions of the model about hiring and firing costs: (1) they generate persistence in employment or, in our case, a positive probability of no change in employment; and (2) they generate a wedge between marginal productivity and wage, that is positive when hiring, and negative when firing. To identify adjustment costs from these statistics we should control for autocorrelation in unobservable shocks and for selection bias. Autocorrelation in shocks generates persistence in employment, and therefore it can create an upward bias in our estimates of adjustment costs. Selection bias results from the fact that firms tend to hire (fire) when the difference between marginal productivity and wage at the beginning of the period is positive (negative). Again, this can create an upward bias in our estimates of hiring and firing costs. An additional econometric problem stems from the fact that we observe net changes in employment, but not gross changes, i.e., new contracts, dismissals and quits. This is a common problem in most firms' or establishments' datasets (see Hamermesh, 1993, p. 398). However, our dataset contains information on severance payments on a firm-year basis. This information makes possible to distinguish between those periods where actual dismissals have occurred and those where the negative change in employment is the result of workers' retirements or quits.

The estimation of this structural model presents an additional advantage. Based on the estimated model, we can perform experiments which allow us to understand the contribution of different factors to the estimated effects of the reform. Furthermore, we can study the effects of hypothetical labor market reforms.

Summary of Results

Our estimates of unit firing and promotion costs, based on revealed preference, are 51% (*s.e.* = 4.8%) and 10% (*s.e.* = 4.6%) of the gross annual wage of permanent workers, respectively. It is important to underline that this estimate is significantly larger than the one obtained when we do not distinguish between quits and dismissals in negative employment changes, i.e., 33% (*s.e.* = 7.7%). Our estimate of the productivity differential between permanent and temporary workers is 20% (*s.e.* = 2.9%). The model provides a good fit to the data, and explains the path of job turnover rates and temporary employment after the reform.

Experiments using the estimated model show that, in the steady state, the reform increases total employment between 2.5% and 4.5%, and job turnover, between 5 and 7 percentage points. This increase in total employment is similar to the one associated with a reduction in firing costs (for every type of contract) from 50% to 25% of the annual wage. Therefore, we obtain important effects of the reform on the level and the variability of

employment. However, the effect on output (below 1%) and on the value of a firm (below 2%) are very small, and they contrast with the sizable effects associated with a reduction in firing costs. Compared with a reduction in firing costs, the introduction of temporary contracts leads to excess turnover and employment of low-experience (and hence low productivity) workers. This has negative effects on firms' productivity and profits. At the maximum duration of a temporary contract, there is a jump in the marginal cost of a worker. This makes firms to dismiss workers that would not be fired if the relationship between firing costs and experience were smoother. This result is consistent with Cabrales and Hopenhayn (1997), who find a peak in the hazard rate of the duration of contracts at the legal limit of a temporary contract.

Finally, we obtain that firing costs have an important negative effect on Spanish employment. According to our estimates, the complete elimination of these costs would increase employment around 12%. The effects on output and on the value of a firm are also large, i.e., 11% and 14%, respectively. However, the effect on employment is nonlinear with respect to the size of the reduction in firing costs. Moderate but important reductions in firing costs (e.g., from 50% to 40% of the annual wage) lead to negligible effects on employment and small effects on output and on the value of a firm.

The remainder of the paper is organized as follows. Section 2 presents the model. In Section 3 we describe our data and present preliminary evidence on the effects of the reform. Estimation and econometric issues are discussed in Section 4. Sections 5 and 6 present estimation results and experiments, respectively. Concluding remarks are given in Section 7.

2 The model

This section presents a labor demand model with two types of labor contracts: fixed-term (or temporary) contracts and indefinite-duration (or permanent) contracts. Our model builds on Cabrales and Hopenhayn (1997). However, the differential in productivity is not the result of the introduction of temporary contracts, but of returns to firm-specific experience. Before the introduction of temporary contracts there were also experienced and unexperienced workers with high and low productivity, respectively. This aspect is important for the evaluation of the productivity effects of the reform. We also incorporate hiring costs, promotion costs, and different wages for temporary and permanent contracts. These extensions are relevant for our empirical results.

2.1 Firms' decision problem

Time is discrete and indexed by t. For the sake of simplicity, we omit in this section the firm index. There are two levels of workers' productivity associated with two levels of firm-specific experience. Efficiency units of labor depend on the number of experienced and unexperienced workers as follows:

$$L_t = n_t + \lambda\ m_t, \tag{1}$$

where L_t represents efficiency units of labor; n_t and m_t are the number of workers whose experience is lower and higher than T^* periods of firm-specific experience, respectively; and $\lambda \in [0, 1]$ is a parameter representing the relative productivity of unexperienced workers. Both T^* and λ are technological parameters, and we assume T^* is equal to 1 period. Therefore, m_t is the number of new hirings at period t.

The production technology of a firm is represented by the production function

$$y_t = F(L_t, \eta_t, A_t), \tag{2}$$

where y_t is real output; η_t is an idiosyncratic productivity shock; and A_t is an aggregate shock. The function $F(.)$ is continuous and twice differentiable, with $F_L > 0$, $F_\eta > 0$, $F_{LL} < 0$, $F_{L\eta} > 0$ and $F_L(0, \eta) = +\infty$ for any η. The productivity shocks, η_t and A_t, follow first order Markov processes with transitional density functions $\phi_\eta(\eta_{t+1}|\eta_t)$ and $\phi_A(A_{t+1}|A_t)$, which are continuous and twice differentiable in both arguments.

As we said earlier, there are two types of labor contracts, fixed-term (or temporary) and indefinite-term (or permanent). Two characteristics distinguish temporary and permanent contracts in our model. First, firing workers with permanent contracts entails a severance payment, but there are not firing costs associated with the dismissal of temporary workers. Second, a temporary contract is only for one period. After this period, the firm should decide whether to dismiss the temporary worker or to promote him to a permanent position. Since all unexperienced workers have the same productivity and receive the same wage, there is no reason to offer permanent contracts to unexperienced workers. Furthermore, the legal limit to the duration of a temporary contract implies that it is not possible to have experienced workers with this type of contract. Therefore, in the model with temporary contracts, n_t and m_t represent permanent and temporary employment at period t, respectively.

The firm decides new temporary contracts, m_t, promotions of temporary workers to permanent positions, h_t, and dismissals of permanent workers, f_t. Therefore, the number of permanent workers at period t is:

$$n_t = n_{t-1} + h_t - f_t. \tag{3}$$

The firm faces costs of hiring, firing and promoting workers. We consider linear adjustment costs as in Bentolila and Bertola (1990), Bertola (1992), and Hopenhayn and Rogerson (1993), among others, but distinguish between hiring costs and promotion costs.

$$AC(m_t, h_t, f_t) = \theta^H \; m_t + \theta^P \; h_t + \theta^F \; f_t, \tag{4}$$

where $\theta^H \geq 0$ is the unit hiring cost; $\theta^P \geq 0$ is the unit cost of promotion; and $\theta^F \geq 0$ is the cost of firing permanent workers. A third component of the profit function is the wage bill, $w_t^n n_t + w_t^m m_t$, where w_t^n and w_t^m are the wages of experienced and unexperienced workers, respectively. For the moment, we assume that the vector of wages $w_t = (w_t^n, w_t^m)'$ follows a first order Markov process with transition density function $\phi_w(w_{t+1}|w_t)$, that is continuous and twice differentiable.

At period t, the firm knows the initial stocks of workers, n_{t-1} and m_{t-1}, technological shocks, and wages, and it decides hirings, promotions and dismissals to maximize the expected discounted stream of current and future profits. There is uncertainty about future technological shocks and wages. Therefore, the decision problem at period t is:

$$\max_{\{m_t \geq 0 \ ; \ 0 \leq h_t \leq m_{t-1} \ ; \ f_t \geq 0\}} \quad E_t \sum_{j=0}^{\infty} \beta^j \ \Pi_{t+j} \tag{5}$$

where the firm's one-period profit is:

$$\Pi_t = F(n_t + \lambda m_t, \eta_t, A_t) - w_t^n \ n_t - w_t^m \ m_t - AC(m_t, h_t, f_t), \tag{6}$$

and $\beta \in (0,1)$ is the discount factor. It is straightforward to see that the vector of state variables in this problem is $s_t = (n_{t-1}, m_{t-1}, w_t, \eta_t, A_t)'$. However, if $(\theta^P + \theta^F) > 0$, a firm will never promote temporary workers and fire permanent workers simultaneously. This implies that the decision about permanent workers can be represented in terms of the net change $d_t \equiv h_t - f_t$, where $f_t = -I(d_t < 0)d_t$ and $h_t = I(d_t > 0)d_t$. Therefore, the profit function can be re-written as:

$$\begin{aligned} \pi(s_t, d_t, m_t) &= F(n_{t-1} + d_t + \lambda m_t, \eta_t, A_t) - w_t^n \ (n_{t-1} + d_t) - w_t^m \ m_t \\ &- \theta^H m_t - \theta^P I(d_t > 0) d_t + \theta^F I(d_t < 0) d_t \end{aligned} \tag{7}$$

Under previous assumptions this decision problem is stationary Markov, and value function and optimal decision rules are time invariant (i.e., Blackwell's Theorem holds). Since the decision problem does not depend on calendar time, we omit for the rest of this section the subindex t, and use N and M to denote n_{t-1} and m_{t-1}, respectively. The Bellman's equation of this problem is:

$$V(s) = \max_{\{m \geq 0 \ ; \ d \leq M\}} \ \pi(s, d, m) + \beta \ EV(N + d, m, w, \eta, A) \tag{8}$$

where $V(.)$ is the value function, and $EV(.)$ is the expected next period value function:

$$EV(N + d, m, w, \eta, A) = \int V\left(N + d, m, w', \eta', A'\right) \ \phi_w(dw'|w) \ \phi_\eta(d\eta'|\eta) \ \phi_A(dA'|A) \tag{9}$$

2.2 Optimal decision rule

To characterize the solution of this model we make the simplifying assumption that the constraint $d \leq M$ is never binding. That is, there are always enough temporary workers to be promoted to permanent positions. This assumption simplifies very much the solution of the model, and it is strongly supported by our data.[2] Implicitly we are assuming that the probability of promotion is so low that intertemporal considerations play a very minor role in the decision about temporary workers. In terms of the parameters of the model, this condition holds (with probability close to one) if $(w^m + \theta^H)/\lambda$ is small enough relative to $w^n + \theta^P$. Under this simplifying assumption, the stock of temporary workers is not a state variable, i.e., $s = (N, w, \eta, A)'$.

Lemma 1 presents the characterization of the optimal decision rule. Before, we introduce the following definitions:

$$L^*(w^m, \eta, A): \quad F_L(L^*, \eta, A) = w^{m*} \equiv \frac{w^m + \theta^H}{\lambda} \tag{10}$$

and:

$$G_n(n, w, \eta, A) = F_L(\max\{n, L^*\}, \eta, A) - w^n + w^{m*} I(L^* > n) + \beta\ EV_n(n, w, \eta, A) \tag{11}$$

where $EV_n(.)$ is the partial derivative, with respect to permanent employment, of the expected value function. We prove in Appendix 1 that the value function is differentiable at any point, and therefore this partial derivative exists. L^* is the optimal employment level if all contracts were temporary, but with permanents' productivity. $G_n(n, w, \eta, A)$ is the intertemporal marginal profit with respect to permanent employment, gross of current adjustment costs, and once we have taken into account the decision for temporary employment.

LEMMA 1: Optimal decision rule

The problem in equation (8) has a unique solution with the following optimal decision function:

$$d^*(s) = \begin{cases} n^P(w, \eta, A) - N & if \quad G_n(N, w, \eta, A) > \theta^P \\ 0 & if \quad -\theta^F \leq G_n(N, w, \eta, A) \leq \theta^P \\ n^F(w, \eta, A) - N & if \quad G_n(N, w, \eta, A) < -\theta^F \end{cases} \tag{12}$$

[2]For 98% of the observations with positive temporary employment at period $t-1$, $(n_t - n_{t-1})$ is lower than m_{t-1}. Obviously, that is not the case for firms with zero temporary employment. However, the proportion of these firms was small in 1993 (lower than 16%) and, according to our model, it should be zero in the steady-state.

and:

$$m^*(s) = \begin{cases} \frac{1}{\lambda}\{L^*(w^m,\eta,A) - N - d^*(s)\} & if \quad L^*(w^m,\eta,A) > N + d^*(s) \\ 0 & if \quad L^*(w^m,\eta,A) \leq N + d^*(s) \end{cases} \tag{13}$$

where $L^*(.)$, $n^F(.)$, and $n^P(.)$ are implicitly defined by the expressions: $F_L(L^*,\eta,A) = w^{m*}$; $G_n(n^P,w,\eta,A) = \theta^P$; and $G_n(n^F,w,\eta,A) = -\theta^F$.

Proof:

See Appendix 1.

The interpretation of this decision rule is simple. n^P and n^F represent the optimal levels of permanent employment when the firm decides to increase and decrease, respectively, this type of contracts. Equation (12) shows that it is optimal to hire permanent workers if, given the level of permanent employment at the beginning of the period, the intertemporal marginal profit when promoting workers, net of adjustment costs, is greater than zero. Alternatively, it is optimal to fire permanent workers if the intertemporal marginal profit when firing, net of adjustment costs, is lower than zero. Otherwise, the optimal decision is not to change permanent employment.

The optimal decision rule without temporary contracts would be:

$$d^{NT*}(s) = \begin{cases} n^{NT,H}(w^n,\eta,A) - N & if \quad G_n^{NT}(N,w^n,\eta,A) > \theta^H \\ 0 & if \quad -\theta^F \leq G_n^{NT}(N,w^n,\eta,A) \leq \theta^H \\ n^{NT,F}(w^n,\eta,A) - N & if \quad G_n^{NT}(N,w^n,\eta,A) < -\theta^F \end{cases} \tag{14}$$

where:

$$G_n^{NT}(n,w^n,\eta,A) = F_L(n,\eta,A) - w^n + \beta\ EV_n^{NT}(n,w,\eta,A) \tag{15}$$

The introduction of temporary contracts has several effects on permanent employment. On the one hand, the firm takes account of promotion costs, θ^P, instead of hiring costs θ^H in the decision to increase permanent employment. If $\theta^P < \theta^H$, this effect contributes to increase the level of permanent employment and its sensitivity with respect to wages and productivity shocks. On the other hand, for $n < L^*$, $F_L(L^*,\eta,A) + w^{m*} < F_L(n,\eta,A)$, so that the marginal intertemporal profit G_n is shifted downwards, and the slope of G_n is lower than in the absence of temporary contracts. This has a negative effect on the level and flexibility of permanent employment, and therefore the overall effect on permanent employment is ambiguous. In most of our simulations, and particularly in those based on the estimated parameters of the model, we obtain that the second effect dominates the first, i.e., the introduction of temporary contracts reduces the level and flexibility of permanent employment. The effect on total employment is ambiguous, and it is closely related to the effect of firing costs on employment.

2.3 Two alternative reforms: reduction in firing costs and introduction of temporary contracts

We conclude this section presenting some numerical solutions of the model. These numerical examples illustrate how the effects of two alternative labor market reforms depend on the values of some structural parameters. We consider a Cobb-Douglas production function:

$$F(L_t, \eta_t) = \exp\{\alpha_0 + \eta_t\} L_t^{\alpha_L} \tag{16}$$

The productivity shock follows an AR(1) process with autoregresive parameter ρ and variance of the innovation σ_a^2. For simplicity, we assume that wages are constant (i.e., there are not aggregate supply or demand shocks, and the economy is in steady-state).

Figures 1 to 3 present the effects on employment and output of different reductions in firing costs in the absence of temporary contracts. We fix $\alpha_0 = 1.4$, $\alpha_L = 0.666$, $w^n = 1.0$, and $\sigma_a = 0.20$. The initial level of the unit dismissal cost is 60% of the wage rate. We consider several values for the persistence of productivity shock, ρ, and for hiring costs, θ^H. In Figures 1 and 2 we present the effect on employment, and the effect on output in Figure 3. First, for any value of ρ and θ^H, the change in employment depends nonlinearly on the magnitude of the reduction in firing costs. Moderate reductions in firing costs reduce employment, but larger reductions can increase it. Second, the change in employment after the reform is very sensitive to the values of θ^H and, particularly, of ρ. The lower the hiring costs and the larger the persistence of productivity shocks, the larger the increase in employment. These figures illustrate the importance of having accurate estimates of these parameters in order to evaluate the employment effects of this type of reform. However, for a wide range of values of the structural parameters, we obtain that reductions in dismissal costs lead to sizable positive effects on output (see Figure 3). That is the case even when the reform has modest effects on employment. This finding is consistent with the results in Hopenhayn and Rogerson (1993).

In Figures 4 and 5 we present an example of the employment effects of introducing temporary contracts. We fix $\alpha_0 = 1.4$, $\alpha_L = 0.666$, $\sigma_a = 0.20$, $\rho = 0.80$, $\theta^H = \theta^P = 0$, $\theta^F = 0.60 \times w^n$, and $w^n = w^m = 1$, and solve the model for different values of λ. From examination of these figures we can assert that, to observe fairly large increases in employment, there should be a significant substitution of temporary contracts by permanent contracts. Any rise in the employment level above 3% requires a proportion of temporary employment of at least 20%. Nevertheless, as we illustrate in Section 6, the output gains from a reform which entails a fairly large proportion of temporary employment are much smaller than the ones associated with a reduction in firing costs.

3 Data and descriptive statistics

3.1 Data and variables

The main data set has been taken from the database of the Balance Sheets of the Bank of Spain (CBBE hereafter). This database contains annual information on the balance sheets and other complementary information on economic variables for a large number of Spanish companies. Our sample is an unbalanced panel with 2356 manufacturing firms between 1982 and 1993. The firms included in this sample represent 40% of total Spanish manufacturing value added during the period. Appendix 2 describes the variables used in this paper and presents the sample distribution of the firms by industry and size. Here we concentrate our discussion on the construction of three important variables: temporary employment, wages, and gross changes in permanent employment.

The CBBE contains information, on a firm-year basis, of the number of workers by type of contract (temporary or permanent) and of the average duration (in weeks) of temporary contracts. To maintain measurement consistency, we have calculated temporary employment in annual terms by multiplying the number of temporary employees along the year times the average number of weeks worked by temporary employees and divided by 52.

CBBE reports the firm's total wage bill (which allows to calculate the average wage rate for total employees at the firm-level), but the wage rate for each type of contract is not reported. We use two datasets to obtain information of wages by type of contract: the Wage Distribution Survey (Distribución Salarial en España, DS hereafter), and the Labor Force Survey (Encuesta Piloto de la EPA, 1987, EPA hereafter). DS reports average wages of permanent and temporary employees at 2-digit industry level (21 industries in our data) and by firm size classes (3 groups). EPA is a large micro dataset of the Spanish labor force. Unfortunately, information on wages is only available for the 1987 EPA, and therefore we only have one cross-section of individual wages.

Most firms' or establishments' datasets have information on net employment changes, but not on gross employment changes, i.e., firings, hirings, and voluntary quits. That is also the case in our data. This is an important limitation if one thinks that most labor adjustment costs are associated with firings and hirings but not with quits. In particular, ignoring this problem implies that many negative changes in permanent employment which are the result of workers' voluntary quits will be treated as costly dismissals. Since our estimates of adjustment costs are based on *revealed preference*, this overestimation of the frequency and amount of firings will lead to an underestimation of firing costs. This has serious implications on the evaluation of the effects of a reduction in firing costs. However, the availability of information about severance payments in our data (on a firm-year basis) allows us to provide a solution to this problem. Using this variable we can identify when there have actually occurred workers' dismissals.[3]

Table 1 presents the joint distribution of two discrete variables: the sign of the net change in permanent employment, and the indicator for the existence of severance pay-

[3]Under the Spanish regulation, a permanent worker is entitled to severance payments even if he/she has been working in the firm for only one year. During our sample period, the compensation was 45 days of pay per year of tenure. Although a worker is not entitled to this compensation in the case of *causal dismissal*, Spanish regulation was very narrow in the definition of this concept. For instance, dismissals for economic reasons were not considered as causal. Furthermore, labor courts tend mostly to decide in favor of the worker. Therefore, almost any dismissal implies a severance payment.

ments. CBBE reports information on severance payments between 1986 and 1990. The frequency of no change in permanent employment is relatively large (about 19%).[4] This shows the existence of important persistence in permanent employment, what is consistent with our assumption of kinked adjustment costs. The frequency of job destructions (40.9%) is very similar to the frequency of job creations (40.3%). However, the high proportion of job destructions contrasts with the much smaller frequency of positive severance payments (24.9%). More than two-thirds of the observations with negative changes in permanent employment are associated with zero severance payments. It seems plausible to consider that these cases result from workers' voluntary quits, and, in particular, retirements. Therefore, the substitution of temporary contracts by indefinite contracts has been mostly associated with voluntary attrition of permanent workers. As we will show in Section 5, not taking this into account implies serious biases in the estimates of adjustment costs.

Under the assumption that there are not voluntary quits, the construction of gross changes in employment is: $h_{it} = I(\Delta n_{it} > 0)\Delta n_{it}$, and $f_{it} = -I(\Delta n_{it} < 0)\Delta n_{it}$, where Δn_{it} is the net change in permanent employment for firm i at period t. In this paper we exploit information on severance payments to relax this assumption. In particular, not all negative changes in employment are interpreted as dismissals. We consider:

$$\begin{aligned} h_{it} &= I(\Delta n_{it} > 0)\Delta n_{it} \ , \\ f_{it} &= -I(\Delta n_{it} < 0 \ ; \ sp_{it} > 0)\Delta n_{it} \\ Q_{it} &= -I(\Delta n_{it} < 0 \ ; \ sp_{it} = 0)\Delta n_{it} \end{aligned} \tag{17}$$

where sp_{it} represents severance payments of firm i at period t, and Q_{it} represents voluntary quits. We obtain estimates of our model using these measures as well as the ones that do not take into account the information of severance payments.

Using the previous definition of hirings, firings and voluntary quits, we can obtain measures of workers' quit rates and severance payments per worker. These statistics give us an indication of whether our measures of severance payments and voluntary quits are consistent with aggregate figures from other datasets. Table 2 presents the median of these

[4]Notice that these are actually zeros in the first difference of permanent employment.

variables between 1986 and 1990. The median quit rate, very similar to the one obtained from the Labor Force Survey (EPA), reflects the low workers' turnover in the Spanish economy. The severance payment per worker is between 56% and 78% of the annual gross wage of permanent workers in the firm. For those firms who are firing permanent workers (those with positive severance payments), the cost of severance payments amounts to 0.7% of annual sales. Finally, given that the regulated severance payment is 45 days of pay per year of tenure, the median job experience of a dismissed worker is between 4.5 and 6.2 years.

One might be tempted to use the severance payments per worker in Table 2 as an estimate of θ^F in our model. However, we observe severance payments only for those firms who decide to dismiss workers. If firms differ in the distribution of (firm-specific) experience of their workers, and therefore in their marginal firing costs, there would be a selection bias associated with the estimate in Table 2. That is, we observe that firms tend to dismiss more workers if they face relatively small firing costs. This selection bias implies a downward bias in the estimate of the average marginal firing cost θ^F. The estimates of labor adjustment costs that we use to evaluate the effects of the reform are based on the principle of revealed preference and on the structure of our model.

3.2 Trends in Spanish manufacturing employment, 1982-93

Table 3 reports the path of several statistics related to firms' activity in our sample. The evolution of real output growth shows that the period 1982-1993 covers an expansion, 1986-1989, and a recession 1990-1993. However, the number and the proportion of permanent employees have monotonically decreased along the sample period. The new regulation of temporary contracts was introduced in November 1984. Temporary employment has experienced a sharp growth from 1986 to 1990. Although temporary employment decreased from 1990 to 1993, its share in total employment rose from 2.89 per cent in 1985 to 9.72 per cent in 1993.

Table 3 presents also job creation and job destruction rates for permanent and temporary employment using the statistics proposed by Davis and Haltiwanger (1992).[5] The small job turnover rates for permanent employment contrasts with the very high rates for temporary employment. This is a simple but strong evidence of how firing costs can have very important effects on job turnover rates. The job turnover rates for total employment are smaller than the ones reported by Davis, Haltiwanger and Schuh (1996) for several countries. A reason for this difference is that our statistics are based on firm level data instead of plant level data.

In Table 4 we decompose the job destruction rates of permanent employment in firings and voluntary quits for the sample period at which severance payments were available. Almost 50% of the destruction of permanent jobs between 1986 and 1990 has been associated with workers' voluntary quits. The large firing costs have compelled firms to wait until the retirement of permanent workers to substitute them with temporary employees. This explains the relatively slow process of adjustment to the new steady-state.

3.3 Wage differential between permanent and temporary workers

One of our concerns is the within-firm wage differential between temporary and permanent workers. The wage differential at the aggregate or industry level captures also the correlation between firms' utilization of temporary workers and firms' wages. For instance, the proportion of temporary workers might be lower in those firms paying higher salaries. We want to control for this correlation.

Table 5 presents estimates of the within-firm wage differential between permanent and temporary workers using the EPA and CBBE datasets. The first panel contains a decomposition of the wage differential based on the estimation of a logarithmic wage equation using workers' micro data from the EPA, which includes human capital variables as well as industry dummies. The average log wage differential in this dataset is 0.427, and the contribution of observable human capital variables is 0.259. Age and firm-specific experience explain almost 50% of the whole differential. Our estimate of the average

[5] Notice that these statistics are based on net changes in employment. i.e., Δn_{it}.

return of an additional year of firm-specific experience is 0.080 (0.016), that is a bit larger than the one in Topel (1991). However, industry dummies have also an important contribution. Therefore, the proportion of temporary workers tend to be lower in those industries (and probably firms) that pay higher salaries.

The second panel presents empirical evidence about the wage differential using the CBBE firms' dataset. The idea behind these estimations is that the average wage in a firm depends negatively on the proportion of temporary workers. In particular, it is simple to show that the logarithm of the average wage in firm i at period t is equal to $\ln(w_{it}^m) + (1-\tau)m_{it}/(m_{it}+n_{it})$, where τ is the wage differential between permanent and temporary workers. Since we do not observe $\ln(w_{it}^m)$ at the individual-firm level, we control for this variable using time dummies interacted with industry dummies, and firms' real output. We also control for firm-specific effects applying either within-firms or first differences transformations; in the latter case, we use an instrumental variable procedure. In any case, the estimate of τ is very robust to the inclusion of real output or to the transformation and estimation method. Furthermore, the size of this estimate is very similar to the contribution of human capital variables in the top panel. Very similar results are obtained when we allow the wage differential to vary over time: in that case, the estimates range from 0.272 (0.031) in 1992 to 0.311 (0.031) in 1986. There is thus no evidence of changes in the wage differential over the sample period, which is consistent with the evidence from aggregate data in the 1988-1992 DS dataset.

4 Estimation of the structural model

4.1 The econometric model

Consider a firms' panel dataset with information on output, employment, and wages, $\{N_{it}, d_{it}, m_{it}, y_{it}, w_{it} : i = 1, ..., I; t = 1, ..., T_i\}$. Let θ be the vector of structural parameters of the model, $\theta = \{\alpha, \lambda, \theta^H, \theta^P, \theta^F, \beta, \Psi\}$, where α are technological parameters in the production function; and Ψ are the parameters in the transition probabilities of the state variables. We incorporate an additional state variable, ε_{it}, that represents a variable cost for permanent employment. Therefore, labor costs associated with permanent workers are $(w_{it}^{n}+\varepsilon_{it})n_{it}$. The state variable ε_{it} is unobservable from the point of view of the econometrician, and it can be interpreted as costs associated with monitoring workers and with the welfare of workers in the jobplace. We assume that ε_{it} is *iid* with mean μ_{ε} and variance σ_{ε}^{2}. Our motivation to include this variable is twofold. First, if there is an additional labor cost with mean different to zero ($\mu_{\varepsilon}\neq 0$) but we do not take it into account, our estimate of $\theta^{P}+\theta^{F}$ will be biased. More specifically, we would be estimating $\theta^{P}+\theta^{F}+\mu_{\varepsilon}$, and therefore either firing costs, or promotion costs, or both, would be biased. Second, this additional labor cost is not constant and it thus allows us to avoid an *unsaturated* specification, i.e., a deterministic relationship between observable variables.

Our econometric model consists on the production function,

$$y_{it}=F(n_{it}+\lambda m_{it},\eta_{it},A_{t};\alpha)\,; \tag{18}$$

the marginal condition of optimality for temporary employment,

$$F_{L}(n_{it}+\lambda m_{it},\eta_{it})=\frac{w_{it}^{m}+\theta^{H}}{\lambda}; \tag{19}$$

the marginal conditions of optimality for permanent employment,

$$\begin{aligned} G_{n}(n_{it},w_{it},\eta_{it},A_{t};\theta)&=\varepsilon_{it}+\theta^{P} \quad if \quad d_{it}>0\\ G_{n}(n_{it},w_{it},\eta_{it},A_{t};\theta)&=\varepsilon_{it}-\theta^{F} \quad if \quad d_{it}<0 \end{aligned} \tag{20}$$

and the optimal discrete choice for permanent employment,

$$\begin{aligned} d_{it}>0 \quad & if \quad \varepsilon_{it}<G_{n}(N_{it},w_{it},\eta_{it},A_{t};\theta)-\theta^{P}\\ d_{it}=0 \quad & if \quad G_{n}(N_{it},w_{it},\eta_{it};\theta)-\theta^{P}\leq\varepsilon_{it}\leq G_{n}(N_{it},w_{it},\eta_{it};\theta)+\theta^{F}\\ d_{it}<0 \quad & if \quad \varepsilon_{it}>G_{n}(N_{it},w_{it},\eta_{it};\theta)+\theta^{F} \end{aligned} \tag{21}$$

The unobservables in this model are $\{\eta_{it},\varepsilon_{it},A_{t}\}$.

To estimate this model we proceed in two stages. In the first stage we estimate the production function, and the optimal decision for permanent workers in the second stage.

We use this two-stage approach for two reasons. First, the estimation of the production function is relatively standard. In particular, we need not solve the dynamic programming model. Second, and more importantly, in equations (20) and (21) we have an unobservable variable which is autocorrelated, i.e., η_{it}. Dealing with this issue in a nonlinear model requires to face the well known problem of initial conditions for the unobservables (see Heckman, 1981). In the context of our censored dynamic programming model, this is not only computationally very costly, but it usually implies important identification problems. Our approach exploits the invertibility of the production function with respect to the productivity shock. In particular, we use data on output and inputs to obtain consistent estimates of the productivity shock, and we use these statistics as "observables" in our estimation of the dynamic programming model. This strategy provides consistent and asymptotically normal estimates, and it has been used, in two different contexts, by Berry, Levinshon and Pakes (1995) and Olley and Pakes (1996).

Before we enter in the details of our econometric approach, it is worthwhile to give a brief and stylized description of this method. Let $x_{it} = (N_{it}, d_{it}, m_{it}, w_{it}, y_{it})'$ be the vector of variables for firm i at period t. Under certain assumptions about the stochastic structure of η_{it} (see subsection 4.2 below) it is possible to obtain moment conditions from the production function to estimate the vector of technological parameters and the distribution of the technological shock, i.e., $\theta_1 = (\alpha, \lambda, \rho, \sigma_a^2)$. Using the equations for the optimal decision of permanent employment, and conditioning on x_{it} and η_{it}, it is possible to obtain a set of moment conditions:

$$E(\ h[x_{it}, \eta_{it}; \theta_1, \theta_2]\ ) = 0, \tag{22}$$

where the expected value is taken over the distribution of ε_{it}, and the vector θ_2 contains the rest of parameters which are not included in θ_1. Now, if the production function is strictly monotonic in the productivity shock, we can invert this function to obtain, $\eta_{it} = f(x_{it}; \theta_1)$. Therefore, we can re-write the previous moment conditions as follows:

$$E(\ h[x_{it}, f(x_{it}; \theta_1); \theta_1, \theta_2]\ ) \equiv E(\ \tilde{h}[x_{it}; \theta_1, \theta_2]\ ) = 0. \tag{23}$$

We use a sequential approach to estimate (θ_1, θ_2). First, we estimate θ_1 using the moment conditions from the production function. Then, we solve our estimate $\hat{\theta}_1$ in $\tilde{h}$, and use the moment conditions in (23) to estimate θ_2. We use the results in Newey (1984) to obtain the covariance matrix of $\hat{\theta}_2$ taking into account the sequential nature of the procedure. The rest of this section describes in more detail the two stages.

4.2 First stage: Estimation of technological parameters

The specification of the production function is a Cobb-Douglas in terms of capital and efficiency units of labor. For firm i at period t:

$$y_{it} = \exp\{\eta_{it} + A_t\}\ K_{it}^{\alpha_K}(n_{it} + \lambda\ m_{it})^{\alpha_L} \tag{24}$$

It is well known that the OLS estimation of this equation suffers of endogeneity bias In particular, contemporaneous values of inputs are correlated with the unobservable productivity shock. Furthermore, if the η_{it} are autocorrelated, lagged values of inputs and output are also correlated with the unobservable. Our identification strategy exploits the time persistence in the demand of permanent workers and the Markov structure of the unobservable shocks. We consider the following stochastic structure for the idiosyncratic shock: $\eta_{it} = \delta_i + u_{it}$, where δ_i represents a time-invariant and firm-specific effect, and u_{it} follows an autoregresive process, $u_{it} = \rho u_{i,t-1} + a_{it}$ with $a_{it} \sim iid\, N(0, \sigma_a^2)$. Therefore, we can obtain the following transformation of the previous equation:

$$\begin{aligned} \Delta \ln y_{it} &= \rho\ \Delta \ln y_{i,t-1} + \alpha_K \ln K_{it} - \rho\alpha_K \ln K_{i,t-1} \\ &+ \alpha_L(\Delta \ln[n_{it} + \lambda\ m_{it}] - \rho\ \Delta \ln[n_{i,t-1} + \lambda\ m_{i,t-1}]) + \gamma_t + \Delta a_{it} \end{aligned} \tag{25}$$

where Δ is the time difference operator; and γ_t is an aggregate effect, that depends on A_t, A_{t-1}, and A_{t-2}. If a_{it} is *iid*, values of inputs and output at period $t-2$ and earlier are orthogonal to Δa_{it}. We can thus exploit such orthogonality conditions to estimate $\{\alpha_L, \lambda, \rho\}$ and the $\gamma's$ by GMM. The existence of adjustment costs associated with the demand of permanent employment implies that lagged values of inputs can be good predictors of current permanent employment.

However, this approach has a limitation in our model. Since there is very low persistence in temporary employment, we do not have good instruments (in the sense of good predictors) for this variable. This problem results into an imprecise estimate of λ. For this reason, we exploit the marginal conditions for temporary employment to estimate λ.

$$\ln y_{it} = const + \ln(n_{it} + \lambda\ m_{it}) + \ln w_{it}^{m} + \mu_i + e_{it} \tag{26}$$

The error terms in this equation, τ_i and e_{it}, represent measurement error in wages and output. Notice that the main empirical prediction that we exploit to identify λ is that, if $\lambda < 1$, temporary employment reduces the marginal productivity of labor. We estimate λ using a within-groups nonlinear least squares estimator. We plug this estimate in equation (25) and then estimate α_K, α_L, and ρ by GMM.

4.3 Second stage: Dynamic decision model

In the context of our model, the existence of kinked adjustment costs has two empirical implications: (1) the difference between marginal productivity of labor and wage should be larger when hiring than when firing; and (2) there should be a positive probability of no change in permanent employment. The larger the job turnover costs, the larger the probability of inaction and the larger the differential between marginal productivities when firing and hiring. Both predictions are important to identify the parameters associated with job turnover costs. However, the Euler equations do not exploit the prediction about the probability of inaction. A second problem associated with the Euler equations approach is that they only hold for the subsample of interior solutions. Therefore, there is a potential sample selection bias. For instance, for the subsample of observations where firms are firing, the unobservable variable cost ε_{it} is conditional to $d_{it} < 0$, and therefore it is correlated with observable state variables. In principle, one can control for this selection bias by using reduced form estimates of the discrete choice. However, there are potential gains of efficiency in our estimates of structural parameters if the structural model is exploited to estimate this discrete choice. Furthermore, our structural model implies exclusion restrictions which are important for identification in the context of a sample selection problem.[6]

We propose and implement an econometric approach that combines several results from the literature of estimation of dynamic programming discrete choice models. Let $x_{it} = (w_{it}, \eta_{it}, A_t)$, and define:

$$MP_{it} \equiv MP(n_{it}, x_{it}) \equiv F_L(\max\{L^*_{it}, n_{it}\}, \eta_{it}, A_t) - w^n_{it} + w^m_{it} I(L^*_{it} > n_{it})$$

MP_{it} is the marginal profit (gross of adjustment costs) of permanent employment for firm i at period t. Let $MP^0_{it} \equiv MP(N_{it}, x_{it})$, that is MP^0_{it} is marginal profit if permanent employment at period t were equal to its value at the beginning of the period. Given our estimates of α_L and λ in the first stage, we can obtain consistent estimates of MP_{it} and MP^0_{it}. Now, according to our specification of the production function, the optimal decision for permanent employment can be re-written as:

$$MP_{it} = \begin{cases} (\mu_\varepsilon + \theta^P) - \theta^H \; I^m_{it} - \beta \; EV_n(n_{it}, x_{it}; \theta) + \varepsilon^*_{it} & if \quad d_{it} > 0 \\ (\mu_\varepsilon - \theta^F) - \theta^H \; I^m_{it} - \beta \; EV_n(n_{it}, x_{it}; \theta) + \varepsilon^*_{it} & if \quad d_{it} < 0 \end{cases} \tag{27}$$

and:

$$\begin{aligned} d_{it} > 0 \quad if \quad & MP^0_{it} + \theta^H \; I^{m0}_{it} + \beta \; EV_n(N_{it}, x_{it}; \theta) - \varepsilon^*_{it} > \mu_\varepsilon + \theta^P \\ d_{it} = 0 \quad if \quad & \mu_\varepsilon - \theta^F \leq MP^0_{it} + \theta^H \; I^{m0}_{it} + \beta \; EV_n(N_{it}, x_{it}; \theta) - \varepsilon^*_{it} \leq \mu_\varepsilon + \theta^P \\ d_{it} < 0 \quad if \quad & MP^0_{it} + \theta^H \; I^{m0}_{it} + \beta \; EV_n(N_{it}, x_{it}; \theta) - \varepsilon^*_{it} \leq \mu_\varepsilon - \theta^F \end{aligned} \tag{28}$$

where $\varepsilon^*_{it} \equiv \varepsilon_{it} - \mu_\varepsilon$; $I^m_{it} \equiv I(L^*_{it} > n_{it})$, and $I^{m0}_{it} \equiv I(L^*_{it} > N_{it})$. We assume that $\varepsilon^*_{it} \sim iidN(0, \sigma^2_\varepsilon)$. Apart from the nonlinear function $EV_n(.;\theta)$, the log-likelihood of this model is very standard. It is a switching regression model where the discrete part consists of an ordered probit. We estimate $(\mu_\varepsilon, \sigma_\varepsilon, \theta^H, \theta^P, \theta^F, \beta)$ by partial maximum likelihood. Notice that in a myopic model ($\beta = 0$) we can identify $\theta^P + \theta^F$, but we cannot identify θ^P, θ^F, and μ_ε separately. However, if $\beta > 0$ we can identify all the parameters in the model (see Appendix 3).

[6]Given the structure of adjustment costs in our model, the discrete choice depends on employment at the beginning of the period, but the continuous choice does not depend on this variable.

The main computational issue in this maximum likelihood estimation is to obtain the expected marginal value function $EV_n(.)$. The following Lemma presents a useful expression for $EV_n(.)$.

LEMMA 2:

$$\begin{aligned} EV_n(n,x) &= \theta^P\ E(P^P[n,x'] \mid n,x) - \theta^F\ E(P^F[n,x'] \mid n,x) \\ &+\ E(\ I\{d^*[s'] = 0\}\ \{MP[n,x'] - \varepsilon' + \beta EV_n[n,x']\} \mid n,x) \end{aligned} \tag{29}$$

where $P^P(n,x)$ and $P^F(n,x)$ are the probabilities of promotion and firing, respectively, conditional on (n,x) and integrating over the distribution of ε.

$$P^P(n,x) = \Pr(d^*[s] > 0 \mid n,x) \qquad ; \qquad P^F(n,x) = \Pr(d^*[s] < 0 \mid n,x)$$

Equation (29) is a contraction mapping in $EV_n(.)$.

Proof:

See Appendix 1.

Given this Lemma, it is possible to estimate θ by Maximum Likelihood using a nested fixed point algorithm (Rust, 1987, 1994). However, such algorithm requires to solve the dynamic programming problem (fixed point) as many times as the number of iterations in our search for the ML estimates. When the dimension of the space of state variables is relatively large, as it is in our case, this is computationally very demanding. For this reason, we use an alternative algorithm, proposed by Aguirregabiria and Mira (1998), to obtain the partial MLE.[7] The main idea of this algorithm is to obtain a sequence of pseudo maximum likelihood estimators based on approximations to the marginal value function. Given one of these pseudo maximum likelihood estimators, the approximation to the value function is updated, and a new pseudo maximum likelihood estimator is obtained using the new approximation. In the limit, the approximation becomes the true marginal value function and the pseudo MLE is the actual partial MLE. This approach reduces very much the number of policy iterations needed to estimate the model (e.g., in

[7] It is a partial MLE because the transition probabilities of the state variables are estimated separately in a first stage.

this paper we need only 5 policy iterations to estimate the model). The reduction in the number of policy iterations is at the expense of a larger number of hill-climbing iterations to obtain the pseudo MLE, but these are computationally much cheaper when the state space is relatively large. Appendix 3 describes this algorithm in more detail.

5 Estimation results

5.1 Estimation of technological parameters

Table 6 presents the estimates of the technological parameters. The top panel contains estimates of λ using the marginal conditions of optimality for temporary employment. Since we do not observe the wage of temporary workers at the firm level, we use the aggregate wage at industry-firm size level. We perform within-firm estimation to control for endogeneity due to omitted heterogeneity in firms' wages. Furthermore, we control for endogenous firms' exit by means of a second order polynomial in the estimated probabilities of exit. These probabilities have been estimated using a probit model where the explanatory variables are the observable state variables and time and industry dummies. Our estimate of λ shows that the productivity of a temporary worker is on average 80% of the productivity of a permanent worker. This estimate of λ is very precise and robust. In particular, we obtain very similar estimates of λ when we use time dummies interacted with industry dummies instead of our aggregate measure of $\ln(w_{it}^m)$, or when we allow λ to vary over time.

It is interesting to compare this value of λ with our estimate of the wage differential in Table 5. According to these estimates, the wage ratio between permanent and temporary workers is very close to the ratio of their relative productivities, i.e., $w^n/w^m = 1.26$ and $1/\hat{\lambda} = 1.25$. Why are permanent workers employed if they are more expensive than temporary workers even after we adjust for their productivities? There are several potential explanations. One is that there might exist certain complementarity between permanent and temporary workers. However, estimates of the production function allowing for this complementarity show that it is very small and not significant. A second possible explanation is that the current situation is not an equilibrium: in the long run, both the amount and the wage of permanent workers will have to come down. But the facts do not support this hypothesis. The relative wage has been stable during the sample period. The share of permanents workers in manufacturing employment continued its decline after 1993, but since 1996 it has become stable (around 80% in the manufacturing industry and 66% percent in the whole economy). Finally, a third potential explanation is based on hiring costs associated with temporary employment. Since temporary workers' turnover is very high (due to the existence of a legal limit to the duration of temporary contracts), even moderate values of θ^H might explain the high share of permanent employment.

The bottom panel in Table 6 presents GMM estimates of the production function, using lags of output and inputs from $t-2$ to $t-4$ as instruments. We exploit all the possible sequential moment conditions for this set of instruments (see Arellano and Bond, 1991). The specification tests do not present evidence against the specification and the choice of instrumental variables. Tests of autocorrelation in the first-difference of the residuals (statistics m_1 and m_2) show no evidence of second order autocorrelation, and therefore lags $t-2$ to $t-4$ of endogenous variables are valid instruments. Furthermore, the p-value of the Hansen-Sargan test of overidentifying restrictions is relatively high. Finally, the null hypothesis of no selection bias due to endogenous exit is clearly rejected.

The first column presents unrestricted estimates of the production function parameters (i.e., unrestricted λ, and no constant returns to scale). The parameter estimates are not very precise, particularly in the case for λ. This parameter is associated with the proportion of temporary workers, and this variable is weakly instrumented. Furthermore, the estimate of α_K seems to be downward biased, which is a common result in the literature on estimation of production functions (see Griliches and Mairesse, 1995, for a recent survey of this literature). Therefore, we also estimate the production function imposing constant returns to scale and our estimate of λ in the top panel of Table 6. Not very surprisingly, the specification is not rejected and we obtain more precise estimates for the rest of parameters of interest. Our estimates of the persistence and the standard deviation of the idiosyncratic shock, i.e., ρ and σ_a, are very precise. It is important to underline that those specifications with, either uncorrelated shocks or without firm-specific fixed effects, were clearly rejected. In both cases the residuals were serially autocorrelated and the overidentifying restrictions were strongly rejected.

5.2 Estimation of the dynamic decision model

Table 7 presents partial maximum likelihood estimates of the structural parameters $\{\theta^H, \theta^P, \theta^F, \mu_\varepsilon, \sigma_\varepsilon\}$. These estimates are obtained using a discount factor equal to 0.95, that corresponds to a 5.3% annual interest rate.[8] We report estimates of four different specifications, with and without voluntary quits; and with homogeneity and heterogeneity in employment adjustment costs. In the specification with homogeneous costs, we consider labor adjustment costs at period t to be proportional to the aggregate average wage at that period:

$$\theta_t^H = \phi^H \; \bar{w}_t^m; \; \theta_t^P = \phi^P \; \bar{w}_t^n; \; \theta_t^F = \phi^F \; \bar{w}_t^m$$

In the specification with heterogeneous costs, labor adjustment costs for a certain firm are proportional to the firm-level wage:

$$\theta_{it}^H = \phi^H \; w_{it}^m; \; \theta_{it}^P = \phi^P \; w_{it}^n; \; \theta_{it}^F = \phi^F \; w_{it}^m$$

In both cases, we report estimates of ϕ^H, ϕ^P, and ϕ^F.[9]

The consideration of heterogeneous adjustment costs does not have important effects on the estimates, either with or without quits. The firing cost parameter seems slightly downward biased in the model with homogeneous costs, and the estimate of σ_ε drops down when we consider heterogeneity. But, apart from σ_ε, the parameters do not change significantly. The goodness-of-fit (likelihood ratio index) improves when we consider het-

[8] Our estimate of β in the unrestricted model was 0.916 (*s.e.* = 0.085). This estimate is too small compared to the real interest rates during the sample period (between 3% and 6%). However, our estimates of the remaining parameters barely changed for values of β between 0.86 and 0.98.

[9] Estimates of wages of permanent and temporary workers at the firm level were obtained using the average firm's wage, the proportion of temporary workers, and the estimated wage differential $\tau = 1.26$.

erogeneous costs, though this is something that we would expect when we introduce additional variability in the explanatory variables.

Nevertheless, the distinction between costly and non costly separations increases very significantly the estimate of the firing cost parameter. It is important to notice that the goodness of fit of the model improves importantly when we consider voluntary quits. That is, the model explains better the discrete dependent variable which exploits information on severance payments to define firings. When voluntary quits were assumed out, we do not find significant differences between hiring and promotion costs, what would imply that hiring costs would be lower than promotion costs in monetary terms.

The point estimates for the unit firing cost and the unit promotion cost are 51.1% and 9.8% of the gross annual wage of permanent workers, respectively. This firing cost is sizeable, though slightly lower than the average severance payment per worker in Table 2. The unit hiring cost is 15.9% of the annual wage of temporary workers. In monetary terms, this is very close to the unit promotion cost. The model provides a good fit to the data, with a likelihood ratio index close to 30%. Furthermore, the paths of aggregate variables from simulations of the estimated model match very well the observed paths during the sample period, i.e., aggregate employment, proportion of temporary workers, and job turnover rates of permanent and temporary workers.

6 Experiments

We use the estimated model to evaluate the effects, on employment, job turnover, productivity and firm's value, of the introduction of temporary contracts. We also compare these effects with those associated with a halving in firing costs for all type of workers. The following parameters are the same in the pre- and post- reform models.

$$\begin{array}{llll} \beta = 0.95\ ; & \lambda = 0.795\ ; & \theta^F = 0.511 * w^n\ ; & w^n = 3.07\ ; \\ \alpha_0 = 2.96\ ; & \rho = 0.691\ ; & \theta^H = 0.159 * w^m\ ; & w^n/w^m = 1.26\ ; \\ \alpha_L = 0.698\ ; & \sigma_a = 0.196\ ; & & \end{array}$$

In the model without temporary contracts, the promotion cost is zero, and the firing cost for unexperienced workers is $\phi^{Fm} = \phi^F = 0.511$. In the model with temporary contracts, ϕ^{Fm} is zero, and the promotion cost is $\phi^P = 0.098$. In both cases we consider the same relative productivity between experienced and unexperienced workers, i.e., $\lambda = 0.795$. Furthermore, we assume that the reform does not affect the relative wage of experienced and unexperienced workers.

Table 8 presents the results of these experiments. The introduction of temporary contracts had important positive effects on employment (3.7% increase) and job turnover (5.8 percentage points increase). The effect on employment is very similar to the one from a 50% reduction in firing costs. However, while the introduction of temporary contracts had small effects on output and firm's value (0.9% and 1.6% increases, respectively), these effects appear to be very important in the case of the reduction in firing costs (3.9% and 5.6%, respectively). Compared with the reduction in firing costs, the introduction of temporary contracts implies an excess of unexperienced workers (19.5% versus 9.8%) and therefore a reduction in average productivity. Furthermore, temporary contracts lead to an *excess* turnover of unexperienced workers. In particular, the number of hirings with temporary workers is more than twice the amount of hirings under the hypothetical reduction in firing costs. This fact also contributes to a smaller increase in the value of firms.

How sensitive are these effects to small changes in the parameters? To answer this question, we have solved the model (i.e., the benchmark model and the two experiments) for fifty random draws of the vector of parameters in a 99% confidence region around the point estimates of θ^H, θ^P and θ^F. Notice that, since we are fixing the rest of parameters, this is a "worst case scenario" for our uncertainty about the effects of the reform. In particular, the proportion of temporary employment and the employment effects of the introduction of temporary workers are very sensitive to the value of the ratio $\lambda w^n/(w^m + \theta^H)$. But, given this ratio, the sensitivity of the effects of the reform to particular values of λ, θ^H and w^n/w^m is very low. The fact that we have not taken into account the covariance between the estimates of λ, θ^H and w^n/w^m implies that we are overestimating our uncertainty about the effects of the reform.[10] We find that the effects on job turnover are quite robust, i.e., between 4.8 and 7.1 percentage points. This is also the case for the effect on employment of a reduction in firing costs (an increase between 2.3% and 4.1%). As we have mentioned, the proportion of temporary employment and the employment effects of the introduction of temporary workers are very sensitive to the value of the ratio $\lambda w^n/(w^m + \theta^H)$. However, for proportions of temporary employment between 16% and 22%, the employment effects of introducing temporary contracts is between 2.7% increase and 4.7% increase.

Figures 6 to 8 present the effects on employment, output and firm's value of several reductions in firing costs. The effects on employment are nonlinear with respect to the magnitude of the reduction in firing costs. According to our estimates, the hypothetical elimination of firing costs would increase (manufacturing) employment by 12%. However, a one-third reduction (from 51% to 34% of the annual wage) implies a 2.3% increase in employment. The effects on output and firm's value are more linear with respect to the reduction in firing costs: in particular, a one-third reduction in firing costs implies a 2.3% increase in output and a 3.6% increase in the firm's value .

7 Concluding remarks

Using panel data of Spanish manufacturing firms, we have estimated a dynamic labor demand model and evaluated the effects of a reform that introduced temporary contracts in 1984. We find important effects of the reform on employment and job turnover. However, compared with a hypothetical reduction in firing costs for all contracts, the effects of the reform on output and value of a firm are very modest. This is explained by the different proportion of low firm-specific experience workers under the two reforms. The introduction of temporary contracts leads to larger increases in employment and job turnover of low experience workers, and therefore to a lower improvement in productivity and firms' profits. We also find that firing costs have a very important negative effect on Span-

[10]Since we have not jointly estimated λ, θ^H and w^n/w^m, we do not have estimates for their covariances.

ish employment. The hypothetical elimination of these costs would increase employment (12%), output (11%), and firm's value (14%).

We have concentrated our analysis on manufacturing employment. However, the proportion of temporary contracts is much larger in the service industry. This might suggest smaller returns of firm-specific experience and larger employment effects of the reform in the service industry. However, this will depend on the values of the rest of structural parameters, which can be different in the two industries (e.g., persistence of idiosyncratic shocks, technological parameters, wage differential). Due to data limitations, our specification of the relationship between productivity and firm-specific experience is inevitably simple. Availability of data sets matching information of individual workers and firms would allow a much richer specification of this learning process. Finally, but very importantly, our model does not take into account that a reduction in firing costs may have negative effects on the bargaining position and the wage of permanent workers. If so, we would be probably underestimating the effect on employment of a reduction in firing costs. The answer to this question requires to introduce wage bargaining in our labor demand model. We consider these as interesting issues for further research.

Appendix 1: Proofs of Lemmas

Proof of Lemma 1.

The decision of temporary employment is static. Since the one-period profit function is strictly concave in m, it is simple to show that, given current permanent employment n, the optimal amount of temporary workers is:

$$\tilde{m}(n, w^m, \eta, A) = \begin{cases} \frac{1}{\lambda}\{L^*(w^m, \eta, A) - n\} & if \quad L^*(w^m, \eta, A) > n \\ 0 & if \quad L^*(w^m, \eta, A) \leq n \end{cases}$$

We can solve $\tilde{m}(.)$ in the one-period profit function $\pi(.)$ to obtain a function that does not depend explicitly on temporary employment.

$$\begin{aligned} \pi^*(N+d, d, x) &= F(\max\{N+d, L^*\}, \eta, A) - w^n(N+d) - w^{m*}\max\{L^* - N - d, 0\} \\ &- \theta^P I(d > 0)d + \theta^F I(d < 0)d \end{aligned}$$

where $x \equiv (w, \eta, A)'$.

Based on this profit function we can define a dynamic decision model where the only decision variable is d. By construction, the optimal decision rule in this new problem is the same as the optimal decision rule for d in the original model. It is simple to verify that $\pi^*(.)$ is: (1) continuous and differentiable with respect to N at any point (included $N + d = L^*$); (2) continuous in d at any point; (3) differentiable with respect to d at any point except $d = 0$; and (4) strictly concave with respect to (N, d). Therefore, we can apply Theorem 9.8 in Stokey and Lucas (1987) to prove that the optimal decision rule exists and it is a continuous function (not a correspondence), and that the value function is strictly concave in N.

Our proof for the differentiability at any point of the value function is heuristic. Consider a sequence of finite horizon problems with time horizon $T = 1, 2, \ldots$. For $T = 1$, it is straightforward to prove that the value function (i.e., one-period profit evaluated at the optimal choice) is differentiable. Now, by induction, it is possible to prove that the value function of any finite horizon problem is differentiable. Finally, if the profit function is bounded, the value function of the infinite horizon problem is equal to the limit as T goes to infinite of the value function of the finite problem (see Puterman 1995).

Let n^P and n^F be the optimal levels of permanent employment if the firm decides to increase and to reduce n, respectively,

$$\begin{aligned} n^P(x) &= \arg\max_{\{n\}} \; G(n, x) - \theta^P d. \\ n^F(x) &= \arg\max_{\{n\}} \; G(n, x) + \theta^F d. \end{aligned}$$

Since $G(.)$ is continuous, differentiable, and strictly concave, n^P and n^F are functions, and they are implicitly defined by equations: $G_n(n^P, x) = \theta^P$, and $G_n(n^F, x) = -\theta^F$. Furthermore, the concavity of $G(.)$ implies that n^F is always larger than n^P. It is clear that if $n^P > N$ the optimal decision for permanent employment is $d^* = n^P - N$. Alternatively, if $n^F < N$ the optimal decision is $d^* = n^F - N$. Notice that both cases are mutually exclusive (because $n^F > n^P$). Taking into account the strict concavity of $G(.)$, we can represent these two cases in terms of inequalities for the marginal profit at $n = N$.

$$\begin{aligned} n^P(x) &> N \Leftrightarrow G_n(N, x) > \theta^P \\ n^F(x) &< N \Leftrightarrow G_n(N, x) < -\theta^F \end{aligned}$$

That is, it is optimal to increase (reduce) permanent employment when the marginal intertemporal profit, at the initial level of permanent employment, is greater (lower) than zero. The other possible case is $n^P \leq N \leq n^F$. Again, this case can be represented in terms of inequalities for the marginal intertemporal profit.

$$n^P \leq N \leq n^F \Leftrightarrow -\theta^F \leq G_n(N,x) \leq \theta^P$$

The marginal profit at $n = N$ is positive from the left and negative from the right. Therefore, $n = N$ is the maximum of the intertemporal profit function, and the optimal decision is $d^* = 0$.

Proof of Lemma 2.

By Lemma 1, the value function $V(N,x,\varepsilon)$ is continuous and differentiable at any point with respect to all its arguments. Furthermore, the transitional densities of the state variables are continuous and differentiable. Therefore,

$$EV_n(n,x) \equiv \partial E(V[n,x',\varepsilon'] \mid n,x)/\partial n = E(\partial V[n,x',\varepsilon']/\partial n \mid n,x).$$

Given the form of the optimal decision rule for permanent employment, the Bellman's equation can be written as follows:

$$\begin{aligned} V(N,x,\varepsilon) &= I(d^*[s] > 0)\left\{\pi^*(n^P, n^P - N, x, \varepsilon) + \beta E(V[n^P, x', \varepsilon'] \mid n^P, x)\right\} \\ &+ I(d^*[s] = 0)\left\{\pi^*(N, 0, x, \varepsilon) + \beta E(V[N, x', \varepsilon'] \mid N, x)\right\} \\ &+ I(d^*[s] < 0)\left\{\pi^*(n^F, n^F - N, x, \varepsilon) + \beta E(V[n^F, x', \varepsilon'] \mid n^F, x)\right\} \end{aligned}$$

Therefore, the partial derivative of the value function with respect to N is:

$$\begin{aligned} \partial V[N,x,\varepsilon]/\partial N &= I(d^*[s] > 0)\ \theta^P \\ &+ I(d^*[s] = 0)\left\{MP^0(N,x) - \varepsilon + \beta\ EV_n(N,x)\right\} \\ &+ I(d^*[s] < 0)\ (-\theta^F) \end{aligned}$$

And:

$$\begin{aligned} EV_n(n,x) &= E(I\{d^*[s'] > 0\} \mid n,x)\ \theta^P \\ &+ E\left(I\{d^*[s'] = 0\}\left\{MP(n,x') - \varepsilon' + \beta\ EV_n(n,x')\right\} \mid n,x\right) \\ &+ E(I\{d^*[s'] > 0\} \mid n,x)\ (-\theta^F) \end{aligned}$$

It is simple to verify that Blackwell's sufficient conditions for a contraction (monotonicity and discounting) hold.

Appendix 2: Data appendix

The sample consists on an unbalanced panel of non-energy manufacturing firms with a public share lower than 50 percent reported to the Bank of Spain's Central Balance Sheet Office from 1982 to 1993. To obtain the final sample of 2,356 firms we have eliminated those for which some of the following variables were negative or took implausible values: book value of capital stock, sales, gross output, total labor costs, permanent employment, and temporary employment.

Employment. Number of employees is disaggregated in permanent and temporary employees. To maintain measurement consistency, number of temporary employees is calculated in annual terms by multiplying the number of temporary employees along the year times the average number of weeks worked by temporary employees and divided by 52.

Real wages. Nominal wages for permanent and temporary workers at the 2 digits industry level and for different firm sizes were obtained from the 1988 and 1992 *Distribución Salarial en Espana* (Source: Spanish Institute of National Statistics, hereinafter INE). This measures were deflated using Retail Price Indexes at 2 digits industry level (Source: INE).

Output. Gross output at retail prices is calculated as total sales, plus the change in finished product inventories and other income from the production process, minus taxes derived on the production (net of subsidies). Real output has been obtained using as deflator the Retail Price Index at 3 digits industry level.

Table A.1
Distribution of firms by 2-digit industry and by size
Unbalanced panel 1982-1993 (2356 firms)

		Small	*Med1*	*Med 2*	*Large*	*Total*
Iron, steel	Abs. freq.	5	8	10	22	45
and metal	% by ind.	11.11	17.78	22.22	48.89	100.00
(22)	% by size	1.29	0.94	1.73	4.10	1.91
Bldg. materials	Abs. freq.	27	88	34	33	182
glass, ceramics	% by ind.	14.84	48.35	18.68	18.13	100.00
(24)	% by size	6.98	10.29	5.89	6.15	7.72
Chemicals	Abs. freq.	39	99	76	92	306
	% by ind.	12.75	32.35	24.84	32.07	100.00
(25)	% by size	10.08	11.58	13.17	17.13	12.99
Non-ferrous	Abs. freq.	38	103	53	31	225
metal	% by ind.	16.89	45.78	23.56	13.78	100.00
(31)	% by size	9.82	12.05	9.19	5.77	9.55
Basic	Abs. freq.	29	52	47	33	161
machinery	% by ind.	18.01	32.30	29.19	20.50	100.00
(32)	% by size	7.49	6.08	8.15	6.15	6.83
Office	Abs. freq.	0	1	0	3	4
machinery	% by ind.	0.00	25.00	0.00	75.00	100.00
(33)	% by size	0.00	0.12	0.00	0.56	0.17
Electric	Abs. freq.	11	29	24	35	99
materials	% by ind.	11.11	29.29	24.24	35.35	100.00
(34)	% by size	2.84	3.39	4.16	6.52	4.20
Electronic	Abs. freq.	3	8	10	14	35
	% by ind.	8.57	22.86	28.57	40.00	100.00
(35)	% by size	0.78	0.94	1.73	2.61	1.49
Motor vehicles	Abs. freq.	8	21	25	36	13
	% by ind.	8.89	23.33	27.78	40.00	100.00
(36)	% by size	2.07	2.46	4.33	6.70	3.82
Ship	Abs. freq.	3	2	2	6	13
building	% by ind.	23.08	15.38	15.38	46.15	100.00
(37)	% by size	0.78	0.23	0.35	1.12	0.55
Other	Abs. freq.	2	5	5	6	18
motor vehicles	% by ind.	11.11	27.78	27.78	33.33	100.00
(38)	% by size	0.52	0.58	0.87	1.12	0.76
Precision	Abs. freq.	2	8	3	4	17
instruments	% by ind.	11.76	47.06	17.65	23.53	100.00
(39)	% by size	0.52	0.94	0.52	0.74	0.72

Table A.1 (cont.)
Distribution of firms by 2-digit industry and by size
Unbalanced panel 1982-1993 (2356 firms)

		Small	*Med1*	*Med 2*	*Large*	*Total*
Non-elaborated	Abs. freq.	23	83	46	48	230
food	% by ind.	23.04	36.09	20.00	20.87	100.00
(41)	% by size	13.70	9.71	7.97	8.94	9.76
Food, tobacco	Abs. freq.	53	51	31	45	180
and drinks	% by ind.	29.44	28.33	17.22	25.00	100.00
(42)	% by size	13.70	5.96	5.37	8.38	7.64
Basic	Abs. freq.	20	57	53	37	167
Textile	% by ind.	11.98	34.13	31.74	22.16	100.00
(43)	% by size	5.17	6.67	9.19	6.89	7.09
Leather	Abs. freq.	4	16	12	4	36
	% by ind.	11.11	44.44	33.33	11.11	100.00
(44)	% by size	1.03	1.87	2.08	0.74	1.53
Garment	Abs. freq.	11	48	34	22	115
	% by ind.	9.57	41.74	29.57	19.13	100.00
(45)	% by size	2.84	5.61	5.89	4.10	4.88
Wood and	Abs. freq.	21	45	26	8	100
furniture	% by ind.	21.00	45.00	26.00	8.00	100.00
(46)	% by size	5.43	5.26	4.51	1.49	4.24
Cellulose and	Abs. freq.	29	63	42	33	167
paper edition	% by ind.	17.37	37.72	25.15	19.76	100.00
(47)	% by size	7.49	7.37	7.28	6.15	7.09
Plastic	Abs. freq.	22	46	33	17	118
materials	% by ind.	18.64	38.98	27.97	14.41	100.00
(48)	% by size	5.68	5.38	5.72	3.17	5.01
Other	Abs. freq.	7	22	11	8	48
non-basic	% by ind.	14.58	45.83	22.92	16.67	100.00
(49)	% by size	1.81	2.57	1.91	1.49	2.04
Total	Abs. freq.	387	855	577	537	2356
	% by ind.	16.43	36.29	24.49	22.79	100.00
	% by size	100.00	100.00	100.00	100.00	100.00

Note: Small means firm's time average of total employment lower or equal than 25. Med 1 means firm's time average of total employment greater than 25 and lower or equal than 75. Med 2 means firm's time average of total employment greater than 75 and lower or equal than 200. Large means firm's time average of total employment greater than 200.

(1.c) Obtain the vectors $v^{\mu}(\hat{P},\hat{\Psi})$, $v^{P}(\hat{P},\hat{\Psi})$, $v^{F}(\hat{P},\hat{\Psi})$, $v^{MP}(\hat{P},\hat{\Psi})$, and $v^{e}(\hat{P},\hat{\Psi})$, and the values $\{\hat{v}_{it}^{\mu},\hat{v}_{it}^{P},\hat{v}_{it}^{F},\hat{v}_{it}^{MP},\hat{v}_{it}^{e}\}$ for each observation in the sample.

Second stage:

Define the pseudo log-likelihood function:

$$\tilde{l}(\theta_2) = \sum_{i=1}^{I}\sum_{t=1}^{T_i} \Big\{l_{it}(MP_{it}^{0}+\theta^{H}I_{it}^{m0}+\beta ev_n[N_{it},x_{it};\theta_2,\hat{P},\hat{\Psi}],MP_{it}+\theta^{H}I_{it}^{m} +\beta\ ev_n\big[n_{it},x_{it};\theta_2,\hat{P},\hat{\Psi}\big];\theta_2)\Big\}$$

where:

$$ev_n(N_{it},x_{it};\theta_2,\hat{P},\hat{\Psi}) = \mu_{\varepsilon}\ \hat{v}_{it}^{\mu}+(\mu_{\varepsilon}+\theta^{P})\ \hat{v}_{it}^{P}+(\mu_{\varepsilon}-\theta^{F})\ \hat{v}_{it}^{F}+\hat{v}_{it}^{MP}-\sigma_{\varepsilon}\ \hat{v}_{it}^{e}$$

Obtain the pseudo maximum likelihood estimator of θ_2.

This estimate of θ_2 is asymptotically equivalent to the partial MLE (see Aguirregabiria and Mira, 1998). However, if the initial estimates of the conditional choice probabilities are imprecise, the finite samples bias and variance of this estimator can be substantially larger than the ones of the partial MLE. Therefore, we apply a third stage.

Third stage:

(3.a) Based on the previous estimate of θ_2 we obtain new estimates of the vectors of conditional choice probabilities. For instance,

$$\hat{P}^{P} = \Phi\left([MP^{0}+\hat{\theta}^{H}\ I^{m}+\hat{\mu}_{\varepsilon}\ \hat{v}^{\mu}+(\hat{\mu}_{\varepsilon}+\hat{\theta}^{P})\ \hat{v}^{P}+(\hat{\mu}_{\varepsilon}-\hat{\theta}^{F})\ \hat{v}^{F}+\hat{v}_{it}^{MP}-\hat{\sigma}_{\varepsilon}\ \hat{v}_{it}^{e}]/\hat{\sigma}_{\varepsilon}\right)$$

Notice that now these estimates exploit the structure of the model.

(3.b) Using the new conditional choice probabilities, apply (1.c) and the second stage.

(3.c) Apply (3.a)-(3.b) until reaching convergence.

Aguirregabiria and Mira (1998) show that this procedure provides the partial MLE of θ_2. Furthermore, they report very significant improvements in finite sample efficiency even if one applies the third stage only once (i.e., without reaching convergence).

Appendix 3: Estimation of the dynamic structural model

Let $l(\theta)$ the log-likelihood function of the model defined in equations (27) and (28).

$$l(\theta) = \sum_{i=1}^{I}\sum_{t=1}^{T_i} l_{it}(MP_{it}^0 + \theta^H\ I_{it}^{m0} + \beta\ EV_n[N_{it}, x_{it}; \theta], MP_{it} + \theta^H\ I_{it}^m + \beta\ EV_n[n_{it}, x_{it}; \theta]; \theta),$$

where $l_{it}(.)$ is the contribution of observation (i,t) to the log-likelihood function. First, we show that $EV_n(.)$ can be written in terms of known functions of the probabilities of firing and promotion, transition probabilities of observable state variables, and one-period marginal profits.

Using Lemma 2 and taking into account that ε and x are independently distributed:

$$\begin{aligned} EV_n(n,x) &= -\mu_\varepsilon + (\mu_\varepsilon + \theta^P)\ E(P^P[n,x'] \mid n,x) + (\mu_\varepsilon - \theta^F)\ E(P^F[n,x'] \mid n,x) \\ &+ E(MP^{0\prime} \mid n,x) - \sigma_\varepsilon\ E(\tilde{e}[n,x'] \mid n,x)' \\ &+ \beta\ E(P^0[n,x'] \mid n,x)\ E(EV_N[n,x'] \mid n,x) \end{aligned}$$

where $\tilde{e}(n,x) \equiv E(I\{d^*[s]=0\}\varepsilon^*/\sigma_\varepsilon \mid n,x)$. It is possible to show that $\tilde{e}(.)$ is a function of the choice probabilities $P^P(n,x)$ and $P^F(n,x)$. We denote this function by $e(P[n,x])$. In particular, given that ε^* is normally distributed: $e(P[n,x]) = \phi(\Phi^{-1}[P^P(n,x)]) - \phi(\Phi^{-1}[P^F(n,x)])$ where ϕ and Φ^{-1} are the density function and the inverse of the cumulative distribution function for the standard normal.

This recursive expression shows that $EV_n(n,x)$ can be written as a function:

$$EV_n(n,x) = ev_n(n,x; P, MP^0, \Psi, \theta_2)$$

where $\theta_2 \equiv (\mu_\varepsilon, \sigma_\varepsilon, \theta^P, \theta^F, \theta^H, \beta)$. To obtain a closed form expression for ev_n, we consider a discretization of the space of observable state variables, i.e., $(n,x) \in \{z^1, z^2, ..., z^M\}$. We can write the contraction mapping for the marginal value function using the following vector notation:

$$ev_n = -\mu_\varepsilon + (\mu_\varepsilon + \theta^P)\ \Psi\ P^P + (\mu_\varepsilon - \theta^F)\ \Psi\ P^F + \Psi\ MP^0 - \sigma_\varepsilon \Psi\ e(P) + \beta\ \Psi\ P^0\ ev_n$$

where ev_n, P^P, P^F, P^0, MP^0 and $e(P)$ are Mx1 vectors; Ψ is the MxM matrix of transition probabilities of the state variables; and $*$ is the Hadamard or element-by-element product. Solving for ev_n we obtain:

$$\begin{aligned} ev_n &= (I_M - \beta\ \Psi\ P^0)^{-1}[-\mu_\varepsilon + (\mu_\varepsilon + \theta^P)\ \Psi\ P^P + (\mu_\varepsilon - \theta^F)\ \Psi\ P^F + \Psi\ MP^0 - \sigma_\varepsilon \Psi\ e(P)] \\ &= \mu_\varepsilon\ v^\mu(P,\Psi) + (\mu_\varepsilon + \theta^P)\ v^P(P,\Psi) + (\mu_\varepsilon - \theta^F)\ v^F(P,\Psi) + v^{MP}(P,\Psi) - \sigma_\varepsilon\ v^e(P,\Psi) \end{aligned}$$

where v^μ, v^P, v^F, v^{MP}, and v^e Mx1 vectors with the obvious definitions.

The estimation algorithm proceeds as follows:

First stage:

(1.a) Estimate the stochastic processes of η and w, and construct the estimated matrix of transition probabilities $\hat{\Psi}$.

(1.b) Obtain nonparametric estimates of the vectors of conditional choice probabilities, $\hat{P}$.

References

[1] Aguirregabiria, V., and P. Mira (1998), "Swapping the Nested Fixed Point Algorithm: A General Class of Estimators for Discrete Markov Models", mimeo.

[2] Arellano, M. and S.R. Bond (1991), "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations", *Review of Economic Studies,* 58, 277-297.

[3] Bentolila, S., and G. Bertola (1990) "Firing Costs and Labor Demand: How Bad is Eurosclerosis?", *Review of Economic Studies*, 57, 381-402.

[4] Bentolila, S., and G. Saint-Paul (1992) "The Macroeconomic Impact of Flexible Labor Contracts, with an Application to Spain", *European Economic Review*, 36, 1013-1053.

[5] Berry, S., J. Levinsohn, and A. Pakes (1995): "Automobile Prices in Market Equilibrium", *Econometrica,* 63, 841-90.

[6] Bertola, G. (1992): "Labor Turnover Costs and Average Labor Demand", *Journal of Labor Economics*, 10, 389-411.

[7] Bertola, G., and R. Rogerson (1996) "Institutions and Labor Reallocation", mimeo, Canadian International Labor Network Conference.

[8] Cabrales, A., and H. Hopenhayn (1997): "Labor Market Flexibility and Aggregate Employment Volatility", *Carnegie-Rochester Conference Series on Public Policy*, 46, 189-228.

[9] Davis, S. and J. Haltiwanger (1992), "Gross Job Creation, Gross Job Destruction, and Employment Reallocation", *Quarterly Journal of economics*, 107, 819-863.

[10] Davis, S., J. Haltiwanger, and S. Schuh (1996): "Job Creation and Destruction", MIT Press.

[11] Griliches, Z., and J. Mairesse (1995), "Production Functions: The Search for Identification" , NBER Working Paper, No 5067.

[12] European Commission (1996), Labour Market Studies, Several Countries (European Communities, Luxembourg).

[13] European Commission (1997), Labour Market Studies, Several Countries (European Communities, Luxembourg).

[14] Hamermesh, D. (1989): "Labor demand and the structure of adjustment costs", *American Economic Review,* 79, 674-89.

[15] Hamermesh, D. (1993): "Labor demand", Princeton Academic Press.

[16] Heckman, J. J. (1981): "The Incidental Parameters Problem and the Problem of Initial Conditions in Estimating a Discrete Time - Discrete Data Stochastic Process", in C. Manski and D. McFadden (eds.), Structural Analysis of Discrete Data with Econometric Applications. MIT Press.

[17] Hansen, L. P.., and K. Singleton (1982): "Generalized instrumental variables estimation of nonlinear rational expectations models" *Econometrica*, 50, 1269-81.

[18] Hopenhayn, H., and R. Rogerson (1993) "Job Turnover and Policy Evaluation: A General Equilibrium Analysis", *Journal of Political Economy,* 101, 915-938.

[19] Hotz, J., and R. A.. Miller (1993): "Conditional choice probabilities and the estimation of dynamic models", *Review of Economic Studies*, 60, 497-529.

[20] Hunt, J. (1994) "Firing Costs, Employment Fluctuations and Average Employment: An Examination of Germany", NBER Working Paper No. 4825.

[21] Newey, W. (1984): "A Method of Moments Interpretation of Sequential Estimators", *Economic Letters*, 15, 201-206.

[22] Olley, S., and A. Pakes (1996), "The Dynamics of Productivity in the Telecommunications Equipment Industry", *Econometrica,* 64 1263-97.

[23] Pakes, A. (1994): "Dynamic structural models: Problems and prospects. Mixed continuous discrete controls and market interactions", in C. Sims (ed.) *Advances in Econometrics. Sixth World Congress.* Volume 2. Cambridge University Press.

[24] Pfann, G., and F. Palm (1993): "Asymmetric adjustment costs in non-linear labour demand models for the Netherlands and the UK manufacturing sectors", *Review of Economic Studies,* 60, 397-412.

[25] Rust, J. (1987): "Optimal replacement of GMC bus engines: An empirical model of Harold Zurcher", *Econometrica,* 55, 999-1033.

[26] Rust, J. (1994): "Structural estimation of Markov decision processes", in R. E. Engle and McFadden (eds.) *Handbook of Econometrics Volume 4*, North-Holland.

[27] Stokey, N. and R. Lucas (1989): *Recursive methods in economic dynamics*, Harvard University Press.

[28] Topel, R. (1991): "Specific Capital, Mobility, and Wages: Wages Rise with Job Seniority", Journal of Political Economy, 99, 145-176.

Table 1
Distribution of the sign of net changes in permanent employment and the indicator of severance payments
Source: CBBE sample of 2356 manufacturing firms, 1986-1990

		Change in permanent employment			
		Negative	**Zero**	**Positive**	**Total**
Severance payments	**Zero**	2658 (28.5%)	1482 (15.9%)	2861 (30.7%)	7001 (75.1%)
	Positive	1156 (12.4%)	272 (2.9%)	896 (9.6%)	2324 (24.9%)
	Total	3814 (40.9%)	1754 (18.8%)	4857 (40.3%)	9325 (100.0%)

Table 2
Severance payment per worker and workers'voluntary quits (sample medians)
Source: CBBE sample of 2356 manufacturing firms, 1986-1990

	Year				
	1986	**1987**	**1988**	**1989**	**1990**
Severance payment per worker relative to gross wage of permanent workers	56.4%	72.0%	78.0%	64.0%	58.4%
Tenure of a dismissed worker (in years)	4.5	5.8	6.2	5.1	4.7
Severance payment per worker relative to firm's annual sales	0.68%	0.73%	0.74%	0.73%	0.70%
Quit rate	2.4%	1.9%	2.3%	2.5%	3.3%

Table 3
Descriptive Statistics (Weighted averages)
Source: CBBE sample of 2356 manufacturing firms, 1982-1993

	Year											
	1982	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**
Rates of growth (%)												
Real output		4.84	1.19	2.14	4.57	9.98	9.25	7.22	-0.60	0.66	1.16	-2.59
Employment		-0.10	-1.54	-1.44	-1.18	-0.70	1.36	0.03	-2.14	-2.20	-2.60	-5.19
Permanent		-0.09	-1.94	-1.60	-2.00	-1.60	-0.14	-1.73	-1.71	-1.86	-2.34	-4.20
Temporary		-0.49	17.52	4.11	26.41	24.46	35.55	26.39	-7.09	-5.01	-4.88	-13.46
Job creation and job destruction rates (%)												
Total Employment												
Job creation		2.64	1.90	2.46	2.68	2.62	3.84	3.77	2.67	3.29	3.36	2.31
Job destruction		2.75	3.44	3.92	3.86	3.32	2.49	3.74	4.84	5.52	5.01	7.63
Permanent Employment												
Job creation		2.45	1.53	2.16	2.09	1.78	2.53	2.74	2.34	2.87	3.05	2.07
Job destruction		2.55	3.49	3.77	4.11	3.39	2.67	4.49	4.07	4.74	5.41	6.37
Temporary Employment												
Job creation		28.31	35.90	27.72	38.11	37.28	39.56	33.97	20.64	17.51	19.53	12.40
Job destruction		28.80	19.79	23.70	14.78	15.49	10.83	10.66	28.00	22.65	24.53	26.83
Labour shares (in percentage ot total employment)												
Permanent	98.04	97.92	97.29	97.11	96.49	95.58	93.95	92.03	92.37	89.31	89.23	90.28
Temporary	1.96	2.08	2.71	2.89	3.51	4.42	6.05	7.97	7.63	10.69	10.77	9.72

Table 4
Job Destruction of Permanent Workers
Firings and Voluntary Quits: 1986-1990

	1986	**1987**	**1988**	**1989**	**1990**
Job destruction rate	4.11	3.39	2.67	4.49	4.07
Firing rate	1.64	1.97	1.52	2.49	2.39
Quit rate	2.47	1.42	1.15	2.00	1.67
% Firing / Total JD	39.9	58.1	56.9	55.5	58.7

Table 5

Wage differential between permanent and temporary contracts

	Decomposition of wage differential from wage equation[a] Data: Spanish Active Population Survey: (EPA) 1987[b]		
	Mean for Permanents	Mean for Temporaries	Contribution to wage differential
Education	-	-	0.034
Age (in years)	41.24	29.88	0.078
Sex (female)	0.287	0.276	0.002
Firm-spec. exp.	12.98	0.72	0.111
Married	0.73	0.39	0.034
Total human capital	-	-	0.259
Industry	-	-	0.077
Residual	-	-	0.091
Total	-	-	0.427

(a) Specification of wage equation: 10 educational dummies,Age, Age^2, 6 age dummies, 6 firm-specific experience dummies, sex, marital status, 58 industry dummies, and permanent contract dummy.

(b) Spanish Active Population Survey (EPA), 1987. Subsample of "Encuesta piloto" (with information on wages). Number of observations: 1087.

	CBBE data. Firms' panel: 1986-1993 Dep. variable: ln(Firm's average wage)[c]			
	Within-firms OLS	Within-firms OLS	First-diff IV[d]	First-diff IV[d]
$\tau - 1$	0.227	0.291	0.222	0.216
	(0.018)	(0.018)	(0.096)	(0.091)
ln(Real output)	-	0.102	-	0.090
	-	(0.005)	-	(0.007)
Number Obs.	13,382	13,382	10,941	10,941

(c) Estimations include time dummies.

(d) Instruments: Prop. of temporaries at $t-2$ and $t-3$, time dummies and real output.

Table 6
Estimation of Technological parameters
Sample: CBBE 1986-1993

Marginal conditions of temporary employment

Parameters	NLLS	NLLS	Within NLLS	Within NLLS
λ	0.768	0.776	0.800	0.795
	(0.024)	(0.024)	(0.029)	(0.029)
$\ln(w^m)$	1.034	1.000	0.901	1.000
	(0.012)	(-)	(0.021)	(-)
# Obs	8739	8739	8739	8739

White's standard errors robust to conditional heteroskedasticity.

Production function. GMM in First Differences

Parameters	Free λ No CRS	Fixed λ CRS
α_K	0.148	0.302
	(0.106)	(-)
α_L	0.612	0.698
	(0.122)	(0.102)
λ	0.825	0.795
	(0.191)	(-)
ρ	0.673	0.691
	(0.071)	(0.072)
σ_a	0.194	0.196
	(0.031)	(0.031)
# Obs.	10,941	10,941
Tests of 1st and 2nd order residual autocorrelation		
m_1 $(p-value)$	-2.39 (0.00)	-2.41 (0.00)
m_2 $(p-value)$	0.57 (0.58)	0.54 (0.59)
Hansen-Sargan test:		
χ^2 $(p-value)$	43.0 (0.39)	45.9 (0.28)
Wald test of H_0: No endogenous exit		
χ^2 $(p-value)$	47.2 (0.00)	47.8 (0.00)

All the estimations include time and industry dummies and a second order polynomial in estimated probabilities of exit.

Table 7
Dynamic Decision Model
Partial Maximum Likelihood Estimation
Sample period: 1986-1990

	Homogeneous costs		Heterogeneous costs	
	Without quits	With quits	Without quits	With quits
$\phi^F \equiv \frac{\theta^F}{w^n}$	0.297	0.470	0.330	0.511
	(0.081)	(0.056)	(0.077)	(0.048)
$\phi^P \equiv \frac{\theta^P}{w^n}$	0.139	0.108	0.142	0.098
	(0.078)	(0.055)	(0.071)	(0.046)
$\phi^H \equiv \frac{\theta^H}{w^m}$	0.143	0.147	0.154	0.159
	(0.085)	(0.061)	(0.081)	(0.052)
$\tilde{\mu}_\varepsilon \equiv \frac{\mu_\varepsilon}{w^n}$	-0.022	0.088	-0.035	0.092
	(0.098)	(0.084)	(0.092)	(0.055)
$\tilde{\sigma}_\varepsilon \equiv \frac{\sigma_\varepsilon}{w^n}$	0.401	0.277	0.352	0.183
	(0.105)	(0.076)	(0.100)	(0.037)
Number obs.	9875	9875	9875	9875
Log likelihood	-8264.6	-6975.2	-8011.5	-6873.3
Likelihood ratio index	0.200	0.280	0.224	0.291

With heterogeneous costs we specify labor adjustment costs in firm i as proportional to the average wage in firm i.

Table 8
Experiments
Introduction of temporary contracts and reduction in firing costs
Effects on employment, job turnover, output and value of a firm

	Introduction of temporary contracts	Reduction in firing costs from 51% to 25% of the gross wage
Δ% in total employment	3.7	3.5
Job turnover rates (%):		
Total employment	11.2	9.8
Permanent employment	4.6	9.8
Change in job turnover rates:		
Total employment	5.8	4.4
Permanent employment	-0.8	4.4
% of temporaries	19.5	0.0
Δ% in output	0.9	3.9
Δ% in value of a firm	1.6	5.6

Figure 1 (rho=0.40)
Change in employment after reduction in fir. cost

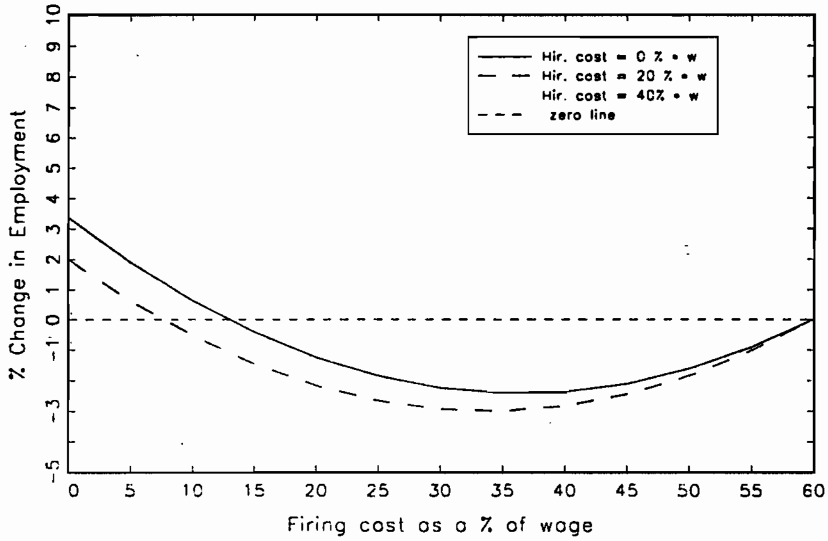

Figure 2 (rho=0.80)
Change in employment after reduction in fir. cost

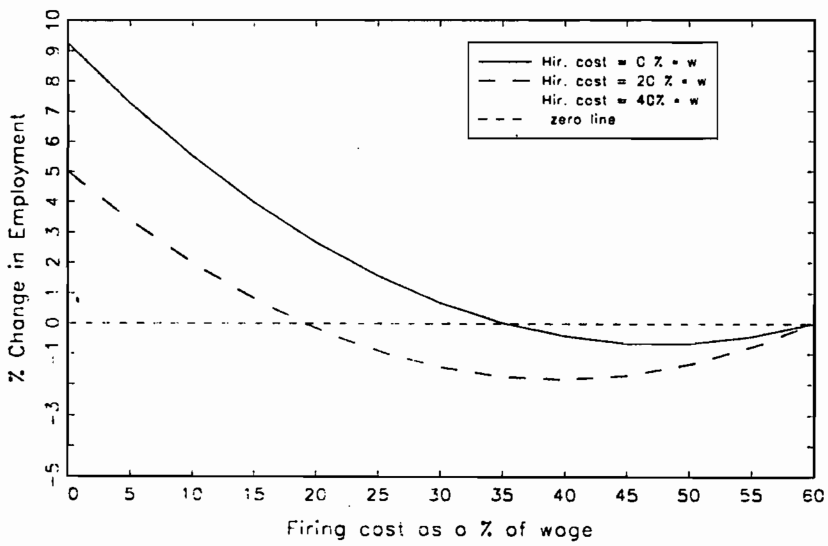

Figure 3
Change in real output after reduction in fir. cost

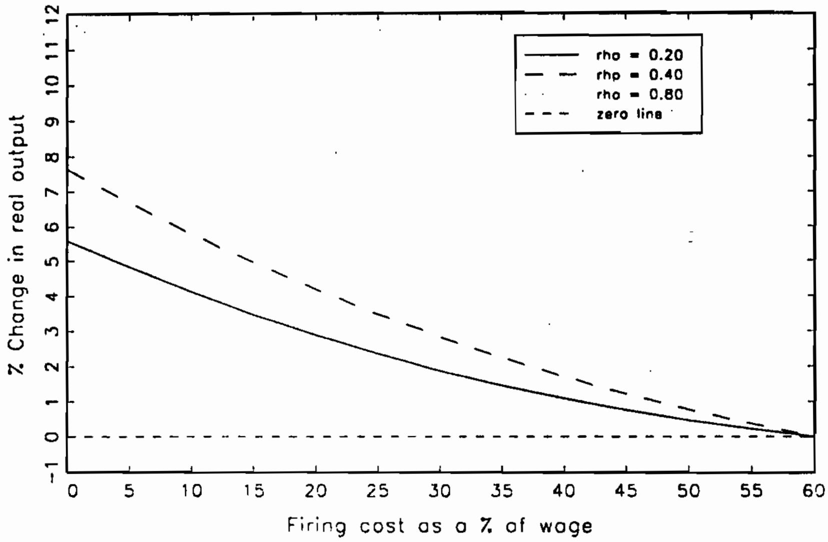

Figure 4
Change (%) in total employment for different relative wages

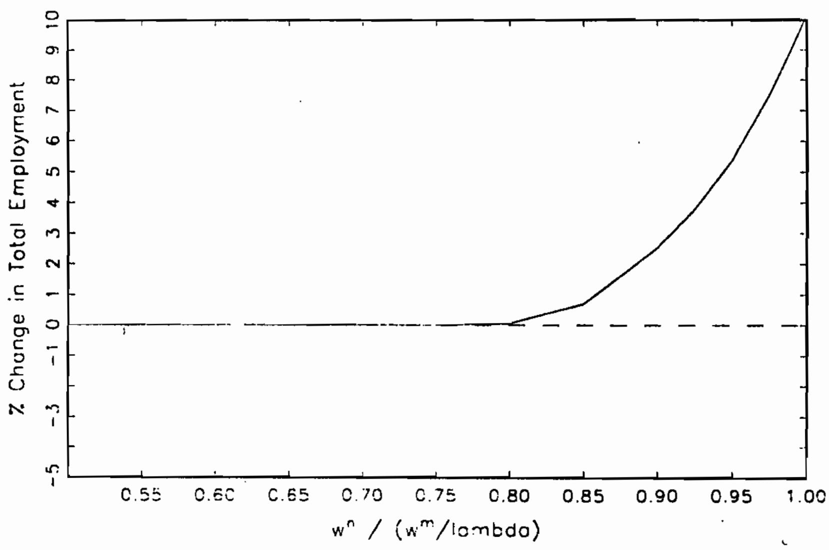

Figure 5
Proportion temporary employment for different relative wages

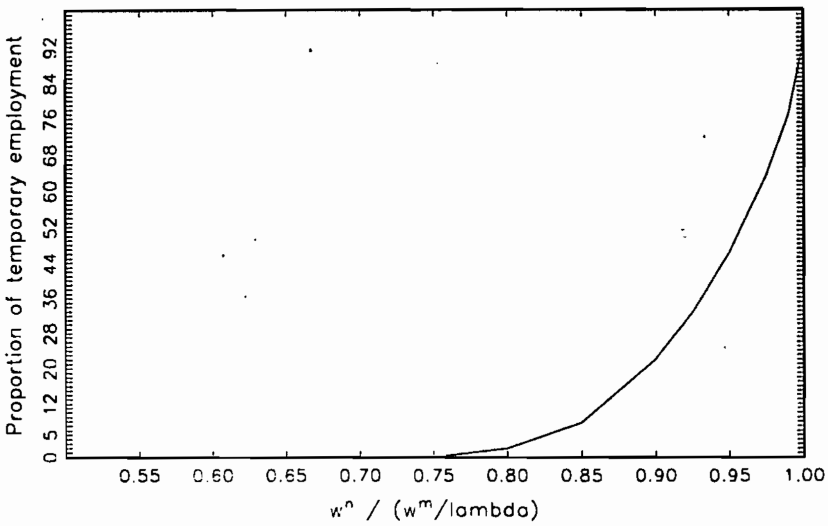

Figure 6
% Change in employment after reduction in firing costs

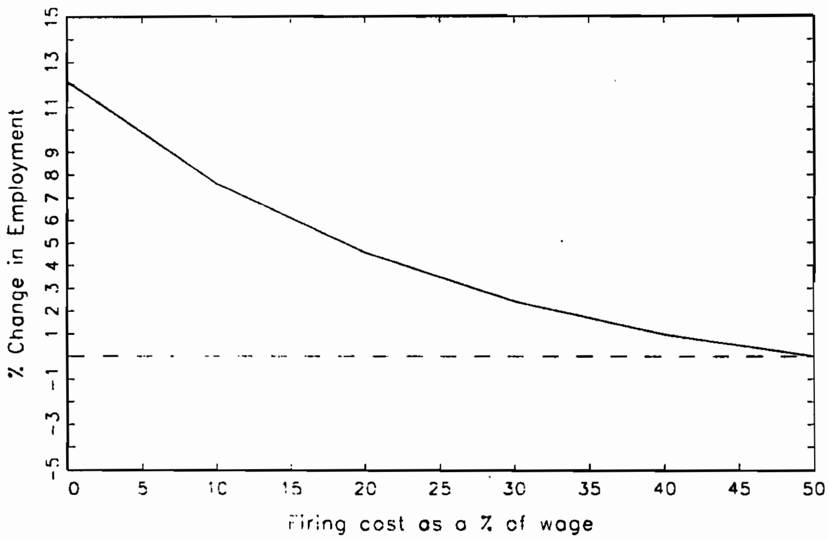

Figure 7
% Change in output after reduction in firing costs

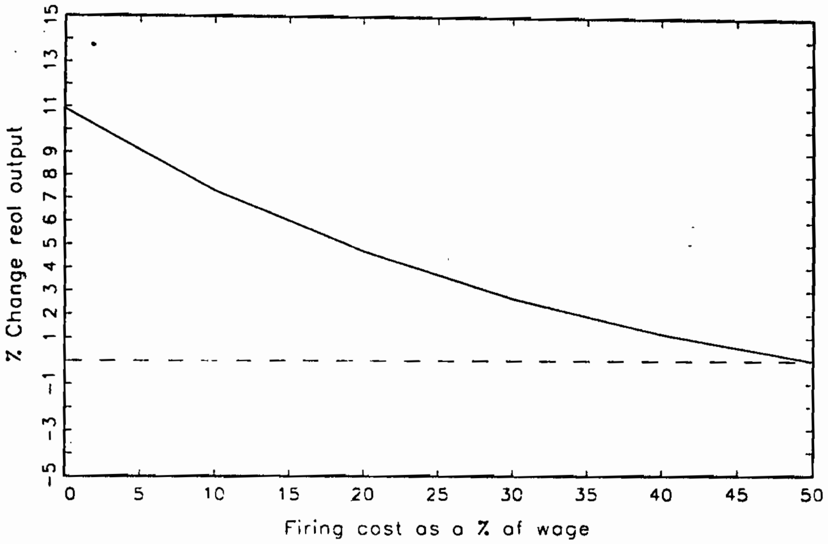

Figure 8
% Change in value of a firm after reduction in firing cost